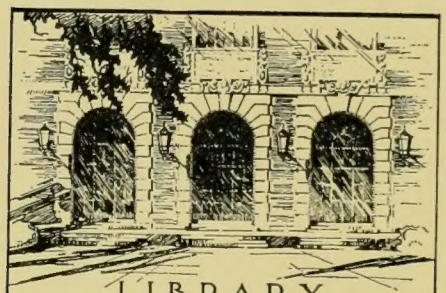
SHOUT
SHARE
IT



LIBRARY
OF THE
UNIVERSITY
OF ILLINOIS

cop.2

NATURAL HISTORY
SURVEY

STATE OF ILLINOIS
William G. Stratton, Governor

DEPARTMENT OF REGISTRATION AND EDUCATION
Vera M. Binks, Director

A SPECTACULAR WATERFOWL MIGRATION THROUGH CENTRAL NORTH AMERICA

Frank C. Bellrose

Biological Notes No. 36

Printed by Authority of the State of Illinois

NATURAL HISTORY
SURVEY DIVISION
Harlow B. Mills, Chief

Urbana, Illinois

April, 1957

NATURAL
HISTORY SURVEY
LIBRARY

MAY 7 1957

A SPECTACULAR WATERFOWL MIGRATION THROUGH CENTRAL NORTH AMERICA

FRANK C. BELLROSE, *Game Specialist, Natural History Survey Division*

An exceedingly large and spectacular waterfowl migration began on the Great Plains of Canada on October 31, 1955, and moved southward in the United States within the Mississippi Flyway on November 1, 2, and 3. Veteran observers concurred that it was the largest single movement of waterfowl since the Armistice Day storm of 1940. Because of the magnitude of this migration and because of the large number of observers who happened to be in the field at the time, the event afforded an unusual opportunity to assemble and analyze the reports of a truly great movement of waterfowl. Also, it afforded an opportunity to study the effect of weather elements on waterfowl migration.

The compilation and analyses of the migration reports, which covered an area that extended from west-central Canada to the Gulf of Mexico, provided information on the routes followed by waterfowl in the Mississippi Flyway, and the altitude, time, and speed of migration under storm conditions. Fortunately, population changes which resulted from the mass migration in several areas of the flyway could be measured, for some censuses were taken immediately before, some during, and some immediately after the migration. Waterfowl biologists throughout the Mississippi Flyway had been taking periodic censuses, and November 1 was a date scheduled for one of these censuses.

ACKNOWLEDGMENTS

Many wildlife biologists, game agents, and refuge managers in the Mississippi Flyway furnished information on their observations of the spectacular waterfowl migration that is the subject of this paper. Several persons furnished material solicited from their colleagues: These were Arthur S. Hawkins of the United States Fish and Wildlife Service; Forrest B. Lee of the Minnesota Department of Conservation; Laurence R. Jahn of the Wisconsin Conservation Department; and William G. Leitch of Ducks Unlimited of Canada. Names and addresses of persons who contributed information on the spectacular flight are listed below.

George C. Arthur, Illinois Department of Conservation, Hamilton, Illinois.

Gus Artus, Missouri Conservation Commission, Bowling Green, Missouri.

Irven Boeker, Upper Mississippi Wildlife and Fish Refuge, La Crosse, Wisconsin.

Homer L. Bradley, Long Lake National Wildlife Refuge, Moffit, North Dakota.

J. R. Caldwell, Ducks Unlimited, Swift Current, Saskatchewan, Canada.

Harry Canfield, Dallas City, Illinois.

J. C. Carlsen, Mud Lake National Wildlife Refuge, Holt, Minnesota.

William D. Carter, United States Fish and Wildlife Service, Winona, Minnesota.

Mike Casey, Minnesota Department of Conservation, Forest Lake, Minnesota.

Robert E. Cleary, Iowa Conservation Commission, Independence, Iowa.

Edward A. Davis, Upper Mississippi Wildlife and Fish Refuge, Grafton, Illinois.

David Donaldson, Arkansas Game and Fish Commission, Paragould, Arkansas.

George Freeman, Ducks Unlimited, Calgary, Alberta, Canada.

William E. Green, Upper Mississippi Wildlife and Fish Refuge, Winona, Minnesota.

Arthur S. Hawkins, United States Fish and Wildlife Service, Minneapolis, Minnesota.

Lewis G. Helm, Missouri Conservation Commission, Columbia, Missouri.

Carl Hunter, Arkansas Game and Fish Commission, Little Rock, Arkansas.

Laurence R. Jahn, Wisconsin Conservation Department, Horicon, Wisconsin.

Harry A. Jensen, United States Fish and Wildlife Service, Jamestown, North Dakota.

Forrest B. Lee, Minnesota Department of Conservation, St. Paul, Minnesota.

Roger A. Lehmann, Minnesota Department of Conservation, St. Paul, Minnesota.

William G. Leitch, Ducks Unlimited, Winnipeg, Manitoba, Canada.

Harry T. Maltby, United States Fish and Wildlife Service, Des Moines, Iowa.

Dale N. Martin, Indiana Department of Conservation, Columbia City, Indiana.

Frank R. Martin, Upper Souris National Wildlife Refuge, Foxholm, North Dakota.

Harvey W. Miller, Nebraska Game, Forestation and Parks Commission, Bassett, Nebraska.

Harland M. Morgan, United States Fish and Wildlife Service, North Platte, Nebraska.

Ray Murdy, South Dakota Department of Game, Fish, and Parks, Pierre, South Dakota.

Harvey K. Nelson, Shiawassee National Wildlife Refuge, Saginaw, Michigan.

Maynard M. Nelson, Minnesota Department of Conservation, Fairmont, Minnesota.

Norman J. Ordal, Minnesota Department of Conservation, Fergus Falls, Minnesota.

E. V. Pierce, Upper Mississippi Wildlife and Fish Refuge, Muscatine, Iowa.

Charles K. Rawls, Jr., Tennessee Game and Fish Commission, Tiptonville, Tennessee.

George B. Saunders, United States Fish and Wildlife Service, Atlanta, Georgia.

Lyle Schoonover, Mingo Swamp National Wildlife Refuge, Puxico, Missouri.

James G. Sieh, Iowa Conservation Commission, Okoboji, Iowa.

Parker Smith, Tennessee Game and Fish Commission, Paris, Tennessee.

M. E. Stempel, Iowa Conservation Commission, Ottumwa, Iowa.

Milton Stenlund, Minnesota Department of Conservation, Ely, Minnesota.

R. T. Sterling, Ducks Unlimited, Wynyard, Saskatchewan, Canada.

Marshall L. Stinnett, United States Fish and Wildlife Service, Peoria, Illinois.

Richard Vaught, Missouri Conservation Commission, Trimble, Missouri.

Peter Ward, Delta Waterfowl Research Station, Delta, Manitoba, Canada.

Jerald J. Wilson, Snake Creek National Wildlife Refuge, Riverdale, North Dakota.

Richard K. Yancey, Louisiana Wild Life and Fisheries Commission, Ferriday, Louisiana.

Douglas M. A. Jones, Meteorologist with the Illinois Water Survey, Urbana, aided in the interpretation of weather maps.

Several members of the staff of the Natural History Survey Division were involved in making this paper ready for publication. Dr. Thomas G. Scott and the Editorial Committee of the Section of Wildlife Research reviewed and improved the manuscript. James S. Ayars edited it. William E. Clark made the photographs for the frontispiece and fig. 1. Charles C. Harper and Forrest D. Loomis prepared the maps and graphs. Loomis made the silhouettes for the cover.

For all assistance that furthered the preparation and publication of this report, the writer is most grateful.

FLIGHTS PRIOR TO THE MASS MIGRATION

Prior to the mass waterfowl migration that began on October 31, 1955, there had been a steady but unspectacular movement of waterfowl into the Mississippi Flyway, fig. 1. Population levels for most of October, 1955, approximated those of October, 1954.

In the northern section of the flyway, there were two pronounced movements of waterfowl previous to October 31, 1955, one in the period October 23-24 and one in the period October 28-30. Jerald J. Wilson reported a constant movement of ducks, largely divers, through the Turtle Mountains of North Dakota on October 23 and 24. Four conservation officers in Wisconsin observed flights of ducks, principally divers, on the same 2 days. Large flights of diving ducks and small flights of mallards *(Anas platyrhynchos)** and other dabbling ducks arrived in Illinois on October 23, 24, and 25.

William G. Leitch reported that large flights of ducks departed on October 29 from the Libau Marshes at the southern end of Lake Winnipeg, Manitoba. Also, ducks were observed leaving the Delta Marsh, some 70 miles west of Libau, on October 30.

J. C. Carlsen reported that heavy movements of gadwalls *(Anas strepera)* were noted at the Mud Lake National Wildlife Refuge near Holt, Minnesota, on October 28 and 29. On October 28, Jerald J. Wilson observed a large movement of coots *(Fulica americana)* from the Garrison Reservoir area of North Dakota. In Wisconsin, seven observers reported the arrival of important flights of ducks, especially scaups *(Aythya)* and other divers, on October 28, 29, and 30. Few, if any, diving ducks arrived at this time in Illinois, but small flights of mallards arrived along the Mississippi River between East Dubuque and Savanna, Illinois.

OBSERVATIONS ON MASS MIGRATION

Perhaps there was no sharp demarcation in time between the duck flights just previous to October 31 and the initiation of the mass movement from the Great Plains of Canada on October 31. There was, however, a demarcation in magnitude: The earlier trickle of southbound waterfowl developed into a flood of migrants on October 31 and the 2 days following.

Canada.--For the area of Calgary, Alberta, George Freeman reported to Ducks Unlimited of Canada that blizzard conditions prevailed there on October 31 and November 1, resulting in the exodus of most of the waterfowl then present. After the storm, only a few

*This and other scientific names from Smith & Parmalee (1955).

flocks of mallards were seen until November 10, when the last of the waterfowl disappeared from the area.

For the Swift Current area, Saskatchewan, J. R. Caldwell made the following comments in his report to Ducks Unlimited of Canada: "Snow coupled with blizzard conditions and very low temperatures caused a mass migration of waterfowl during a three day period, October 31-November 2nd. The peak appeared to be November 1st from the personal observations and reports of the Kee-men and hunters. The storm reached its worst that day in southwest Saskatchewan with high winds and drifting snow making visibility almost nil at times. Birds moved steadily all day southward. By Wednesday, November 2nd, all but a few of the larger lakes in the southwest were closed over. The south Saskatchewan River was full of ice and only a few stragglers (possibly cripples) were seen in the Kindersley area where lakes and sloughs had 3-4 inches of ice on them by November 3rd."

From Wynyard, Saskatchewan, R. T. Sterling reported to Ducks Unlimited of Canada that the arrival of low temperatures and snow during the period of October 31-November 2 caused the mass departure of all the waterfowl then remaining in east-central Saskatchewan. On October 31, several thousand gadwalls migrated through Little Quill Lake. By November 2, the only open water in the area consisted of a few holes on Big Quill Lake, where there were small numbers of mallards.

According to Peter Ward, at the Delta Waterfowl Research Station at the south end of Lake Manitoba in Manitoba, the largest migration of waterfowl he had ever witnessed occurred on November 1, 1955. The flight lasted from 10:00 A.M. until dark, mallards migrating throughout the day and lesser scaups *(Aythya affinis)* from 4:00 P.M. onward. Flocks averaging 70 to 90 birds each crossed the lake shore line at quarter-mile intervals on the average of one flock per minute. Ward estimated that 215,000 ducks passed over.

Ward stated that the migration was very unusual in that the bulk of the mallards passed through the Delta area from the north in 1 day. Most of the waterfowl which had been in the Delta Marsh joined the passing flight. Up to November 1, there had been only the usual drift through that area.

North Dakota.--Harry A. Jensen reported that a mass migration of waterfowl occurred on November 1 and 2 across the breadth of North Dakota from the Red River valley to the Montana line. The flight was only half as large on November 2 as on the preceding day. In 1 hour on November 1, 50 flocks were counted in migration near Dawson. Observers along the Missouri River informed Jensen that it was the heaviest migration they had ever seen; about 85 per cent of the flight was made up of mallards, the remainder being lesser scaups. Approximately 100,000 mallards stopped along the Missouri River from the Garrison Reservoir to the South Dakota line, 25,000 mallards on Kunkel and Horse Head lakes near Dawson, and 35,000 mallards on Lake Ashtabula, north of Valley City. Jensen stated that all flocks flew on a uniform course to the southeast.

Fig. 1.--A steady but unspectacular movement of waterfowl into the Mississippi Flyway preceded the mass migration that began on October 31, 1955.

At the Upper Souris National Wildlife Refuge, Frank R. Martin saw large numbers of mallards and scaups passing down the Souris River valley throughout the day of November 1. He estimated that, at a point east of Foxholm, 1,000 ducks per hour, in flocks varying from 25 to 100 birds each, were passing through a half-mile gap in the valley. East of the valley, waterfowl were present in even greater numbers, but they were more widely dispersed. The flocks flew at heights of 75 to 100 yards or lower – so low that some of the ducks were shot down by hunters.

Homer L. Bradley, at the Long Lake National Wildlife Refuge near Moffit, reported that throughout the daylight hours of November 1 the air was full of ducks in any direction that one might look. The mass movement was similar to one which he had observed on November 13, 1954, but the 1955 flight was larger. All flocks, most of which were composed of mallards, were flying south-southeast; few, if any, flocks stopped in the area on their way through.

South Dakota.--In South Dakota, the peak of the flight occurred on November 1. On that day, Ray Murdy was aviating up the Missouri River from Fort Thompson to the North Dakota line. Murdy reported the following: "Throughout the whole flight we saw indications of a large-scale, daytime mallard migration. As we were flying north we were continually meeting flocks of mallards following the river south. This is the only time we have seen such a movement on the river during the three years we have made the survey. Also, for the first time we saw numerous, scattered flocks of mallards resting on open water where we have never seen mallards before. We had the impression that these were new arrivals that were unfamiliar with the river and had landed to rest before they had reached one of the numerous concentration areas."

Upon returning at night to his home at Webster in northeast South Dakota, Murdy heard from local hunters that there had been a very heavy movement of ducks through that area all day (November 1). The ducks passed through without stopping, and, on November 2, Murdy found that even the waterfowl which had been in the Waubay Hills area the preceding day had departed during the night.

Driving through eastern South Dakota on November 1, James G. Sieh did not notice migrating waterfowl until about 2 P.M., when he observed several flocks flying southward above the prairie hills near Clear Lake, about 10 miles west of the Minnesota line.

Nebraska.--In the Bassett area of north-central Nebraska, Harvey W. Miller observed only a minor duck flight on November 1 and 2. To the east, on the Missouri River, excellent shooting occurred on November 1, 2, 3, and 4. Miller reported that neither the game managers in the Lincoln area, in the east, nor those in the Alliance area, in the west, recorded large movements of waterfowl at that time, but that the game manager for the North Platte area in central Nebraska recorded large flights on the nights of November 1 and 2.

The large flight of waterfowl into the North Platte area was observed also by Harland M. Morgan. He reported that, during the night of November 1, 40,000 ducks and 500 Canada geese *(Branta canadensis)* arrived at the Sutherland Reservoir and that more arrived during the ensuing day, November 2. At the North Platte Reservoir, the number of ducks increased from 2,500 to 15,000. The migration was made up largely of mallards, but with considerable numbers of lesser scaups and smaller numbers of all other ducks indigenous to the area.

Minnesota.--At the Mud Lake National Wildlife Refuge in northwest Minnesota, J. C. Carlsen observed flock after flock of ducks passing through on November 1. The stream of ducks, most of which were mallards interspersed with scattered flocks of divers, consisted of groups of about 25 to 200 birds. Between October 28 and November 2, Carlsen estimated that over 100,000 ducks passed over the refuge. There was very little evidence of migration on November 2.

On November 1, Forrest B. Lee observed great numbers of ducks while he was making an aerial census of waterfowl on east and west transects through the west-central part of the state; the southernmost transect passed a few miles north of Fergus Falls. Lee reported that although he observed some flocks of migrating ducks during the morning, the flight did not reach spectacular proportions until afternoon. From 1:00 to 3:00 P.M., flocks of waterfowl, almost all mallards, were tallied from the airplane at the rate of 75 flocks per hour.

Lee observed that most of the flocks were flying to the southeast but that some were migrating due south. Many flocks were flying as low as 100-150 feet above the ground, and, although most were higher, 700-800 feet appeared to be the highest altitude for those visible. None of the passing waterfowl showed the slightest interest in stopping at any of the innumerable lakes over which they flew.

Norman J. Ordal reported that fisheries personnel of the Minnesota Department of Conservation counted 139 flocks while driving 18 miles from Perham to Detroit Lakes on November 1. The flight was first noticed in that area at about 11:00 A.M.

In northeastern Minnesota, biologist Milton Stenlund noted no indication of a major flight on November 1 or 2 in the Superior National Forest area. Manifestly, the principal flight of waterfowl was farther to the west at that time.

Maynard M. Nelson first noticed the mass flight in the south-central part of Minnesota at 4:30 P.M. on November 1. Between 5:00 and 6:00 P.M., at Pierce Lake in Martin County, he counted 41 flocks, which contained an estimated 4,125 ducks. None of these flocks stopped, but, that night, a multitude of ducks descended on Martin County lakes; large concentrations of ducks were observed by Nelson in that area the following morning.

At Talcott Lake, about 50 miles to the northwest of Pierce Lake, Roger A. Lehmann at 4:15 P.M. noticed the first of many flocks of mallards flying from the north on November 1. From that time until it was too dark to see, he observed a continuous flight to the lake. The flocks of mallards varied from 50 to 300 birds each.

The mass flight was still in progress in some areas of Minnesota on November 2. A short distance north of St. Paul, Mike Casey saw flocks of migrating waterfowl from daylight to 10:30 A.M. Mallards predominated in the flight, which included smaller numbers of scaups, ring-necked ducks *(Aythya collaris),* redheads *(Aythya americana),* canvasbacks *(Aythya valisineria),* and Canada geese. Flocks varied in size from 10 to several hundred birds each. Although large, high-flying flocks continued on in flight, many small, low-flying ones dropped into the Carlos Avery Refuge. The ducks were flying at altitudes that varied from a few hundred feet to heights at which they were barely discernible to observers on the ground.

Mississippi River.--On the Upper Mississippi Wildlife and Fish Refuge south of Winona, Minnesota, William D. [Pete] Carter watched the departure of 25,000 ducks between 7:30 and 8:30 A.M. on November 2. During that hour, flocks of 50 to 150 ducks were taking flight toward the south at about 5-minute intervals, until only 5,000 remained. Farther down the river during the rest of the day, Carter observed a steady flight of ducks southward; none of these ducks appeared to stop. On the following day he observed only a few flocks, all of them flying high and moving southward.

About 175 miles south of Winona on the Mississippi River, near Clinton, Iowa, Dr. William E. Green and Irven Boeker were aviating north at an altitude of 1,200 feet on November 2. Suddenly, at 9:00 A.M., they were surrounded by a heavy flight of ducks heading southeast. As far as they could see on each side, as well as above and below the plane, ducks filled the air. For an hour, Green and Boeker, aviating on a northwesterly course across country to Prairie du Chien, Wisconsin, watched the flight of waterfowl continue. These waterfowl appeared to be taking a short-cut across the big eastward bend of the Mississippi River in northwestern Illinois.

About 70 miles southwest of Clinton, at the Louisa National Wildlife Refuge, adjacent to the Mississippi River near Wapello, Iowa, E. V. Pierce saw the mass duck migration on November 2. Following is his vivid description of it: "Starting at about daylight and lasting without any apparent let-up until about an hour after noon, there took place a migration of ducks, mostly mallards, that simply defies description. If an accurate description could be written, anyone not having seen the migration could not possibly believe or imagine what went on. All the duck hunters who were fortunate enough to be out in the Odessa bottoms at Louisa that day agree that they witnessed the largest and most concentrated flight of ducks they had ever seen in their lives in any single day. There was a strong west-northwest wind mixed with light rain, sleet, and snow. Visibility was extremely limited, but, from within gun range to as far and as high as one could see, the air was literally full of ducks. For about an hour, between 8 and 9, the flight was hardly divided into flocks, but rather appeared to be just one solid drove of birds. As nearly as anyone could tell, this flight came right down the Mississippi and also, in probably greater numbers, from the west and northwest. The great majority of these birds flew right on through this neighborhood, but by evening Louisa Refuge held at least 150,000 mallards."

Forty miles farther downstream, on November 2, at Dallas City, Illinois, Harry Canfield noted rafts of mallards scattered over the river surface at dawn where none had been the evening before. Other flocks of mallards were winging overhead, and a steady flight continued until 11:00 A.M.; at that time a snow shower started, after which the magnitude of the flight sharply diminished. Although mallards made up the bulk of the flight, there were numerous flocks of lesser scaups, ring-necked ducks, and canvasbacks, along with a few flocks of gadwalls and widgeons or baldpates *(Mareca americana).*

Some 30 miles southeast of Dallas City at Colchester, Illinois, hunters saw many flocks of mallards passing southward in the dim light of early dawn on November 2.

From a bluff overlooking the Mississippi River near Hannibal, Missouri, Gus Artus witnessed on November 2 the greatest waterfowl migration he had ever seen. From dawn through the morning, myriads of flocks of southbound ducks were in sight for several miles to the east, over the flat valley lands on the Illinois side of the Mississippi River. His view to the west was limited by hills to a mile or so, but, as far as he could see in that direction, there also were flocks of migrating ducks. By early afternoon, the magnitude of the flight had diminished.

Still farther south in the Mississippi River valley, at Batchtown, Illinois, was Edward A. Davis, who reported that at daybreak on November 2 thousands of newly arrived mallards were resting on the river. For the remainder of the day, flocks filled the air at altitudes ranging from several hundred to 2,000 feet. As the flocks moved southward, only a small fraction of the flying ducks stopped at nearby refuges. Davis estimated that he saw 600,000 to 900,000 ducks, the bulk of which were mallards; with the mallards were smaller numbers of lesser scaups, ring-necked ducks, canvasbacks, pintails *(Anas acuta)*, gadwalls, and widgeons. Unusually large numbers of massed groups of 2,000 or more ducks were in evidence. Reports of hunters and farmers who were near the mouth of the Illinois River on November 2 indicated that ducks migrated in a belt approximately 40 miles wide across Jersey County, Illinois.

Along the Mississippi River in extreme southern Illinois, George C. Arthur first noticed the mass migration at 10:00 A.M. on November 2. The ducks, most of them mallards, were flying between the river channel and the valley bluff; the migration continued at least until dark.

At this point the mass flight extended 60 or 70 miles to the west, at least as far as Lake Wappapello, Missouri. At Mingo Swamp National Wildlife Refuge, adjacent to Lake Wappapello, Lyle Schoonover observed a heavy flight through the area on November 2 and 3. About 50,000 mallards stopped at the refuge, from which there was a gradual departure during the next 10 days.

In driving the 40 miles from Puxico east to Sikeston, Missouri, on the morning of November 2, Schoonover observed scattered flocks of southbound ducks at altitudes of 400 to 1,000 feet. On the same day, Richard Vaught in driving southwest 50 miles from Cape Girardeau to Puxico observed a continual procession of migrating ducks, most of them mallards.

Wisconsin.--There were 22 reports, from many sections of Wisconsin, of unusually large flights of waterfowl between October 30 and November 5. Laurence R. Jahn extracted comments from the reports submitted by field personnel of the Wisconsin Conservation Department. Specific dates relating to the flights were not given in all cases, but two observers reported movements for October 30, two for October 31, one for November 1, seven for November 2, and four for November 3.

Some of the reports regarding waterfowl movements in Wisconsin at that time were as follows: In Burnett County in the northwestern part of the state, a very heavy mallard flight started the evening of October 31; it was still heavier on November 1 and 2. In addition, 75 whistling swans *(Olor columbianus)* were seen flying south over the Crex Meadows on November 2; other swans were reported in migration over Winnebago County on November 2. On November 3, at Lake Poygan, in the same county, 20-30 flocks of swans, numbering 30-75 birds per flock, were observed flying southeast. Peak numbers of ducks were reported on November 2.

Several reports were from the Wisconsin River area in Iowa and Dane counties. One field man in that area reported a good flight of ducks on November 2, with 94 flocks in migration near Arena. Another observer in the same area stated that there were heavy flights of mallards and diving ducks on October 30 and November 2. He estimated that 1,000 ducks passed over in 3½ hours on October 30 and 4,000 in 4½ hours on November 2. Flocks were large, flying high, and heading east, southeast, south, and southwest. The flight was light there on November 3.

A large duck flight was reported on November 2 in Jefferson County, in the southeastern part of the state. In Lafayette County, in the southwestern corner of the state, 10 flocks of geese and many ducks were noted the same day.

Michigan.--Harvey K. Nelson, who for several years had observed waterfowl movements through the Saginaw River valley and Saginaw Bay area of Michigan, in 1955 assisted the Michigan Department of Conservation in periodic waterfowl censuses of that area.

Nelson reported that local hunters saw large flights of ducks, primarily redheads, canvasbacks, and mallards, moving into and through Saginaw Bay on the afternoon of October 31. During an airplane census flight on November 1, he observed small groups of redheads, canvasbacks, and scaups flying over Saginaw Bay from the northwest to the southeast, but, at that time, no mass movement was in evidence. However, on November 2, hunters reported mass flights of ducks and excellent hunting. Migration was further evinced by observation of increased numbers of mallards, black ducks *(Anas rubripes)*, redheads, and scaups in the Saginaw River marshes on November 2 and 3. A major exodus of widgeons took place on those dates.

Iowa.--The flight of waterfowl through Iowa on November 2, according to James G. Sieh, ran into millions of birds. The migration first appeared in the lake region of the northwestern part of the state late in the afternoon of November 1. By daylight the following morning, migration was well underway. Throughout the day, Sieh saw large flocks of mallards pass nonstop over Big Spirit Lake in a southeasterly direction. Other flocks of mallards, which had alighted on Big Spirit Lake during the afternoon or night before, took flight periodically throughout the morning, as they, too, joined the migrating stream of ducks. Only a few flocks of diving ducks departed during the morning, but, late in

the afternoon of November 2, they commenced to leave Big Spirit Lake, where they had rested during the daylight hours. From 4:30 P.M. until dark, hundreds of flocks of lesser scaups and ring-necked ducks departed on a front only 1,000 yards wide from west to east.

Harry T. Maltby reported that, on November 2, 10,000 mallards and 3,500 canvasbacks and redheads plus 2,000 miscellaneous ducks were found resting on the Missouri River between Sioux City, Iowa, and the Missouri line, apparently having arrived the night of November 1-2. Maltby provided the following figures for ducks which alighted on November 2 at lakes in the northwestern and western parts of the state: Round Lake, 3,000 mallards; Storm Lake, 5,000 mallards; Rush Lake, 2,000 mallards; Silver Lake, 750 mallards; and Blackhawk Lake, 3,000 mallards.

Robert E. Cleary, on the banks of the Wapsipinicon River, near Independence, at daybreak on November 2, noted ducks flying to the southeast down the valley in a steady stream; the flight continued until late afternoon. Between 6:30 and 8:30 A.M., divers of all species, even ruddy ducks *(Oxyura jamaicensis),* occurred in the flight. After 8:30 A.M., mallards predominated in the flight; they were followed in order of numbers by pintails, green-winged teals *(Anas carolinensis),* shovelers *(Spatula clypeata),* gadwalls, and widgeons. For the most part, flocks averaged about 100 birds each, all flying at altitudes of several hundred feet.

Near Eddyville on the Des Moines River, M. E. Stempel observed 66 flocks, aggregating 7,000 ducks, between 6:30 and 10:00 A.M. A flock of 10 to 500 ducks passed by every 3 minutes during this period. Afterwards the flight diminished and an increasing overcast reduced visibility; only three large flocks were observed from 10:00 A.M. to 12:00 noon. Between 6:30 and 7:40 A.M., about half of the flocks consisted of divers and the other half of mallards. Later, practically all the flocks were made up of mallards. Most of these ducks were flying straight south toward the Chariton River valley.

Illinois.--In Illinois, the prelude to the 1955 mass migration of waterfowl occurred on November 1, when ducks appeared in the middle reach of the Mississippi River. We first became aware of this movement at 10:00 A.M. while aviating up the Mississippi River from Grafton toward Quincy. From the plane, we saw 20 flocks of mallards flying south at an altitude of 500 feet. Edward A. Davis told us that, on November 1, 2,000 flocks passed down the Mississippi River at Batchtown, Illinois, most of them at altitudes over 1,000 feet. Most of the flocks, made up of mallards, numbered 25 to 50 birds each, but some contained as many as 100 to 200 birds.

By the morning of November 2, it was evident that a tremendous migration of waterfowl was underway in the state. At daybreak, many observers saw a steady stream of ducks, most of them mallards, arriving in the Illinois River valley from the north, northwest, and, occasionally, from the southwest or east. Up and down the valley, throughout the day, the flight continued. Hunters had a "field day" as newly arrived mallards decoyed to almost any kind of call.

At 8:00 A.M., we saw large flocks of mallards wheeling into the Illinois River valley above Havana. Within the next hour, 40 flocks numbering 50 to 100 mallards each were noted flying toward the valley from the east. Twenty miles below Havana, a continuous, almost unbroken stream of mallards passed down the valley throughout the day. Most of the flocks were following the valley, which angles in a southwest direction, but some were leaving the valley to fly directly south over the prairie farm lands. Although the bulk of the ducks appeared to be passing through nonstop, flocks now and then became detached from the passing throng to alight on the lakes and marshes of the Illinois River valley. By nightfall, local duck populations had tripled or quadrupled. The populations were at a peak for only a short time, however. Either many of the recently arrived ducks remained for only a few hours of rest before continuing south, or many of the ducks which had been present at the time the mass flight reached the valley resumed their migration during the night. For example, at Crane Lake, near Bath, the duck population dropped from 120,000 the evening of November 2 to 85,000 by the following morning.

Ducks migrated into the upper Illinois River valley all through November 2. At 2:00 P.M., east of Morris, Marshall L. Stinnett noticed 25,000 mallards dropping into the valley from the northwest. As he proceeded west by car to Bureau, on a highway paralleling the river valley, he observed flocks of mallards continually arriving from the northwest. South of Bureau, the migration of waterfowl was still greater, and, late in the afternoon, Stinnett estimated that 150,000 ducks dropped into the bottomland lakes of the Illinois River between Bureau and Henry.

Indiana.--Dale N. Martin, making aerial flights over Indiana on October 31 and November 1 and 2, saw no indication of a mass waterfowl migration until early on the morning of November 2. Throughout the rest of the day, he observed ducks arriving at the Willow Slough Game Preserve from the northwest and north. The principal migrants were mallards, but considerable numbers of black ducks, gadwalls, green-winged teals, redheads, canvasbacks, scaups, and ring-necked ducks also arrived. Coots departed from Willow Slough the night of November 3.

Missouri.--Lewis G. Helm provided the following excellent review of the 1955 mass waterfowl flight in Missouri: "The impressive duck flight that began on the night of November 1 in Missouri and continued throughout the day of November 2 was the greatest flight of ducks seen by many observers in the state. To many people it rivaled the November 11, 1940, flight in both speed and extent, and the number of ducks involved is reported to be even greater than the 1940 flight.

"There was some indication that the flight into Missouri started on the last day of October, especially in the southeast section of the state. An aerial count of waterfowl was made over the northwest portion of the state on October 31, but only relatively small numbers of ducks were counted on the concentration areas. Squaw Creek Refuge contained 36,000 mallards; Swan Lake, 10,000; while the remainder of north Missouri was estimated to have but 35,000 mallards. Peak numbers of Canada geese had already been reached in north Missouri; approximately 50,000 geese had left the state by October 31.

"November 1 was a mild fall day in north-central Missouri, with only scattered clouds and mild temperatures, which climbed into the high 60's. By evening it was apparent that a change of weather was due. By the morning of the second there was snow and sleet on the ground, and low clouds were racing across the sky from the north and west. Ducks, particularly mallards and green-winged teal, were observed flying just under the cloud ceiling at about 100 feet altitude. Many birds were seen on open water areas of refuges and farm ponds throughout the northern part of the state, and by afternoon observers in all parts of the state reported a heavy movement of ducks. The main lines of flight were along the larger rivers, such as the Mississippi, Missouri, Chariton, and North Grand rivers; however, ducks were seen from points located on uplands in most sections of the state and throughout the Ozarks. Apparently what took place was a broad band of migration from one edge of the state to the other, with the most birds flying along the major river systems.

"The mallard was the main species involved in the flight, but other species were prominent too. The green-winged teal appeared in good numbers throughout the state, with the greatest concentration recorded in the central regions. Lesser scaup moved through the state rapidly and only a relatively few thousand stayed for more than 2 or 3 days. Of an estimated 50,000 scaups moving into and through the state on November 2, only 4,000 could be accounted for on November 5. Smaller numbers of other divers, notably ring-necked ducks, moved through the state during and after November 2.

"Comparing the counts made by aerial inventory on October 31 with ground checks during and immediately after the large flight of ducks, at least 750,000 mallards must have been involved in the flight into and through Missouri.

"An interesting facet of the November 2 flight is the fact that, apart from the very eastern counties, observers in Kansas noted no marked migration of either ducks or geese."

In the Sumner-Brunswick area of Missouri, flocks of low-flying mallards were "pouring over" at daybreak on November 2. Many flocks were dropping out of the passing stream of waterfowl to alight on ponds, creeks, and other small bodies of water which normally are seldom frequented during the fall. The flight continued most of the day, with the ducks flying south and southeast. Near Paris, the flight was entirely toward the southeast.

Tennessee.--Concerning the 1955 mass migration in Tennessee, Parker Smith wrote as follows: "There is no question but that a huge influx of birds occurred on November 2 and 3. Mallards, black ducks, ring-necked ducks, and wood ducks [*Aix sponsa*] were the main species on Kentucky Lake, and mallards, gadwalls, baldpates, pintails, and ring-necked ducks were the major species on Reelfoot Lake."

Charles K. Rawls, at Reelfoot Lake, reported that from 7:30 A.M. until dark on November 2 he saw 15-25 flocks containing 50-100 mallards each passing over at any given moment. Many flocks streaking southward on the heels of a strong north wind attempted to hook into the wind and alight, but were blown backward. By the morning of November 3 the flight was smaller and by noon it was over. This was the largest flight of ducks observed at Reelfoot Lake in the past 10 years.

Arkansas.--Carl Hunter reported that there was no evidence of a mass duck flight in Arkansas on November 1. On November 2, however, radio reports were received from wardens to the effect that large numbers of ducks, mostly mallards, were arriving. This flight was indicated as the largest recorded single movement of waterfowl into the state. The ducks appeared to arrive over the entire eastern part of the state at about the same time.

On November 3, while aviating over northeastern Arkansas, Hunter and David Donaldson saw numerous strings of ducks flying south, some at altitudes as high as 1,500 feet. Near Jonesboro, they watched hundreds of ducks scale down from 1,500 feet to join rafts of ducks already resting on the Claypool Reservoir.

Louisiana.--Richard K. Yancey observed mass flights of mallards, gadwalls, green-winged teals, pintails, and scaups arriving in Louisiana on November 2 and 3. He reported that smaller, but the first important, flights of ring-necked ducks, canvasbacks, redheads, and ruddy ducks also arrived at that time. Increased

numbers of shovelers, baldpates, and coots swelled populations already present.

Yancey made the following statement: "Although the waterfowl flight [of November 2 and 3] descended to a degree like a blanket over Louisiana, it appeared to develop its greatest magnitude along the Mississippi and Red rivers. For the most part, the flocks were traveling in a southerly direction, and the flocks observed were flying principally at altitudes of 300-400 feet. . . . During the course of this early November waterfowl inventory [aerial], migrant flocks could be seen at almost any point over the rice fields of southwestern Louisiana, or in the vicinity of any major body of water in north and central Louisiana."

Dr. George B. Saunders reported that the flight arrived on the Louisiana coast at the Lacassine National Wildlife Refuge on November 3.

POPULATION CHANGES AS A RESULT OF FLIGHT

The effect of the mass migration of 1955 on waterfowl populations in the Mississippi Flyway was pronounced. Waterfowl censuses made in five states, immediately prior to and after this spectacular flight, show more than a three-fold increase in the duck populations of the flyway, table 1. Among the 12 areas for which there are data, the relative increases were similar in all but two areas: Martin County, Minnesota, and Swan Lake National Wildlife Refuge, Missouri, both of which registered a 12-fold increase.

Information on the change in species composition resulting from the mass migration is available for a Minnesota area, the lower Illinois River valley, and the state of Louisiana, tables 2, 3, and 4. In the Minnesota area, table 2, a large ingress of mallards and lesser scaups occurred along with an egress of gadwalls and pintails. In the Illinois River valley, table 3, a sizable ingress occurred in mallards, black ducks, lesser scaups, and canvasbacks concomitant with a sizable egress in widgeons, green-winged teals, shovelers, ring-necked ducks, and coots.

All species of waterfowl but the blue-winged teal *(Anas discors)* increased in numbers in Louisiana, table 4. The influx of migrants was especially pronounced for the mallard, gadwall, green-winged teal, redhead, canvasback, ring-necked duck, and lesser scaup.

The chronology of waterfowl migration in the Illinois River valley in 1954 and 1955 is shown in fig. 2. The population trend for October, 1955, was similar to that for October of the year before. By November 1, 1955, the number present in the Illinois River valley

Table 1.--The increase in waterfowl populations in areas of the Mississippi Flyway which were censused immediately before and after the spectacular waterfowl flight of late October and early November, 1955.

State	Observer	Area	Preflight Population*	Postflight Population*
South Dakota	Ray Murdy	Missouri River	105,543	323,770
Minnesota	Maynard M. Nelson	Martin County	1,364	16,370
Illinois	Edward A. Davis	Calhoun Refuge	53,500	195,000
		Batchtown Refuge	38,000	82,000
	Frank C. Bellrose	Lower Illinois River valley	358,575	814,855
Indiana	Dale N. Martin	Jasper-Pulaski Refuge	1,100	5,500
		Kankakee Refuge	12,000	38,000
		Willow Slough Game Preserve	24,000	40,000
Missouri	Lewis G. Helm	Squaw Creek Refuge	36,000	160,000
		Swan Lake Refuge	10,000	125,000
		Other northern areas	35,000	125,000
Louisiana	Richard K. Yancey	State-wide	477,000	1,481,000
Total			1,152,082	3,406,495

*Figures are based on waterfowl censuses made on the following dates: South Dakota, October 26-27 and November 1; Minnesota, November 1 and 2; Illinois, November 1 and 3; Indiana, October 31 and November 3; Missouri, October 31 and November 5; Louisiana, October 31 and November 4.

Table 2.--The change in waterfowl populations in Martin County, Minnesota, as a result of migration on November 1, 1955.*

Species	Number of Ducks Observed	
	October 31-November 1	November 2
Mallard	1,152	13,495
Gadwall	28	0
Pintail	15	0
Green-winged teal	2	2
Ring-necked duck	20	30
Canvasback	6	20
Lesser scaup	2	2,725
Total	1,225	16,272

*Data provided by Maynard M. Nelson, Minnesota Department of Conservation.

Table 3.--The change in waterfowl populations in the Illinois River valley between Peoria and Meredosia, Illinois, as a result of migration on November 2, 1955.

Species	Number of Ducks Observed	
	November 1	November 3
Mallard	281,975	739,860
Black duck	2,840	7,500
Gadwall	1,805	1,260
Widgeon	5,140	2,765
Green-winged teal	10,275	2,825
Blue-winged teal	100	0
Shoveler	390	45
Pintail	33,450	38,000
Redhead	250	40
Canvasback	910	1,540
Lesser scaup	2,850	9,600
Ring-necked duck	18,080	8,390
Ruddy duck	510	130
Total	358,575	811,950
Coot	87,925	63,200

had risen to 663,000, about the same number as were present on November 2, 1954. By November 3, 1955, the calculated duck population in the area had risen to 1,487,000, whereas on November 2-3, 1954 (2-day census), it was about 693,000. Not until November 14 did the 1954 duck population rise to a peak comparable to that found on November 3, 1955. It thus appears that weather conditions prevalent on October 31 and November 1 and 2, were responsible for accelerating the migration by almost 2 weeks in 1955.

Table 4.--The change in waterfowl populations in Louisiana as a result of migration on November 2 and 3, 1955.*

Species	Number of Ducks Observed	
	October 31	November 4
Mallard	5,000	330,000
Black duck	0	7,000
Gadwall	15,000	225,000
Widgeon	75,000	125,000
Green-winged teal	30,000	220,000
Blue-winged teal	200,000	10,000
Shoveler	30,000	60,000
Pintail	120,000	250,000
Redhead	0	2,000
Canvasback	0	12,000
Ring-necked duck	1,000	20,000
Lesser scaup	1,000	220,000
Total	477,000	1,481,000
Coot	175,000	340,000

*Data provided by Richard K. Yancey, Louisiana Wild Life and Fisheries Commission.

DAILY WEATHER CONDITIONS

The following review of weather conditions leading up to and during the mass migration of waterfowl on October 31 and November 1-3, 1955, was made from weather maps of the United States Weather Bureau and the Meteorological Division of the Canadian Department of Transport. These maps, temperature records, and comments on weather conditions reported by field men of Ducks Unlimited of Canada provided useful means for analyzing the relationship between weather conditions and the mass migration.

October 29.--The weather map for 6:30 P.M., C.S.T., showed a fairly deep low pressure area centered over northeastern Wisconsin. From the low, an eastward-moving cold front extended in a semicircle through western New York, central South Carolina, and north-central Florida. Also from the low, a westward-moving warm front extended northward across James Bay. High pressure areas occurred over Churchill, Manitoba, and the District of Mackenzie.

October 30.--By 6:30 P.M., C.S.T., the cold front had become stationary and extended from Quebec eastward to the coast of New Jersey; the warm front had moved from its October 29 position a short distance northwest to Hudson Bay. The low pressure area that had been centered over northeastern Wisconsin on

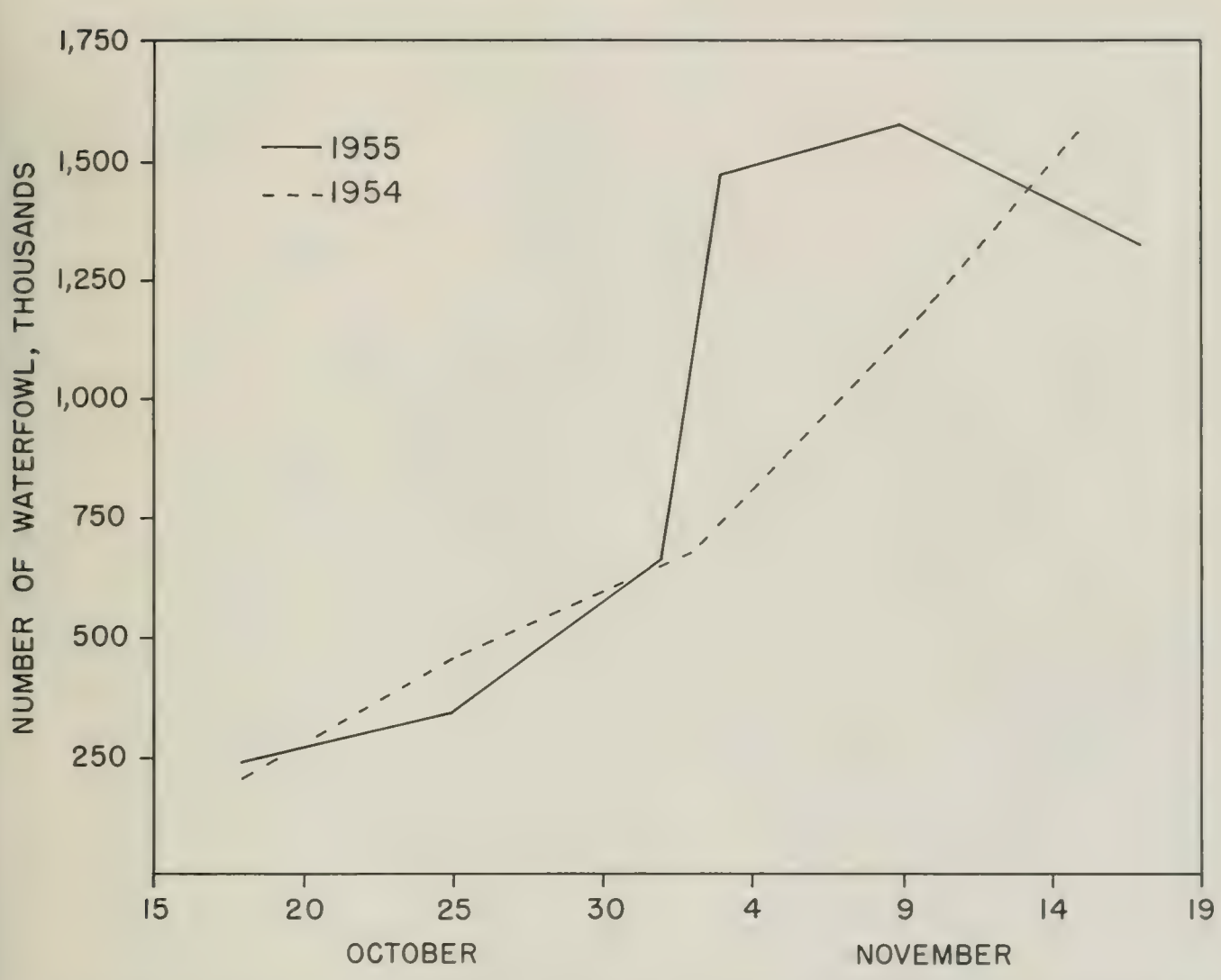


Fig. 2.--Waterfowl populations in the Illinois River valley from mid-October to mid-November, 1954 and 1955, as determined by aerial surveys. The survey on November 3, 1955, covered only half of the waterfowl habitat in the Illinois River valley; the figure for the entire area was calculated from this sample.

October 29 remained there, while another low pressure area had developed in southeastern Alberta and southwestern Saskatchewan. A ridge of high pressure extended from Alaska into the District of Mackenzie.

October 31.--The weather map for 6:30 A.M., C.S.T., fig. 3, showed the low pressure area that had been over Wisconsin had shifted northward to the region west of James Bay and had filled slightly; the low over Alberta and Saskatchewan had remained stationary; and a new low had developed over central South Dakota. A high pressure area had centered over northern Yukon. A synopsis issued by the Canadian Meteorological office stated the following: "The first storm of the winter is centered over eastern Alberta this morning [October 31] and will move southeastward through Montana and North Dakota during the day. Snow has fallen over most regions, with heaviest amounts in Alberta and the Peace River block. Strong winds have caused blowing snow in Alberta and Saskatchewan. As the system moves southward colder air will gradually drop temperatures in all regions."

November 1.--By 6:30 A.M., C.S.T., fig. 4, the low pressure area west of James Bay had deepened and moved northwest to the vicinity of Churchill, Manitoba. The strong high remained centered over northern Yukon. A pronounced cold front of Continental Arctic air was moving southeastward across the Dakotas. A weak cold front of Maritime and Continental Polar air was moving eastward across a number of states that included Michigan and Illinois. The following weather synopsis was issued by the Canadian Meteorological office: "Snow is still falling over the prairies this morning.

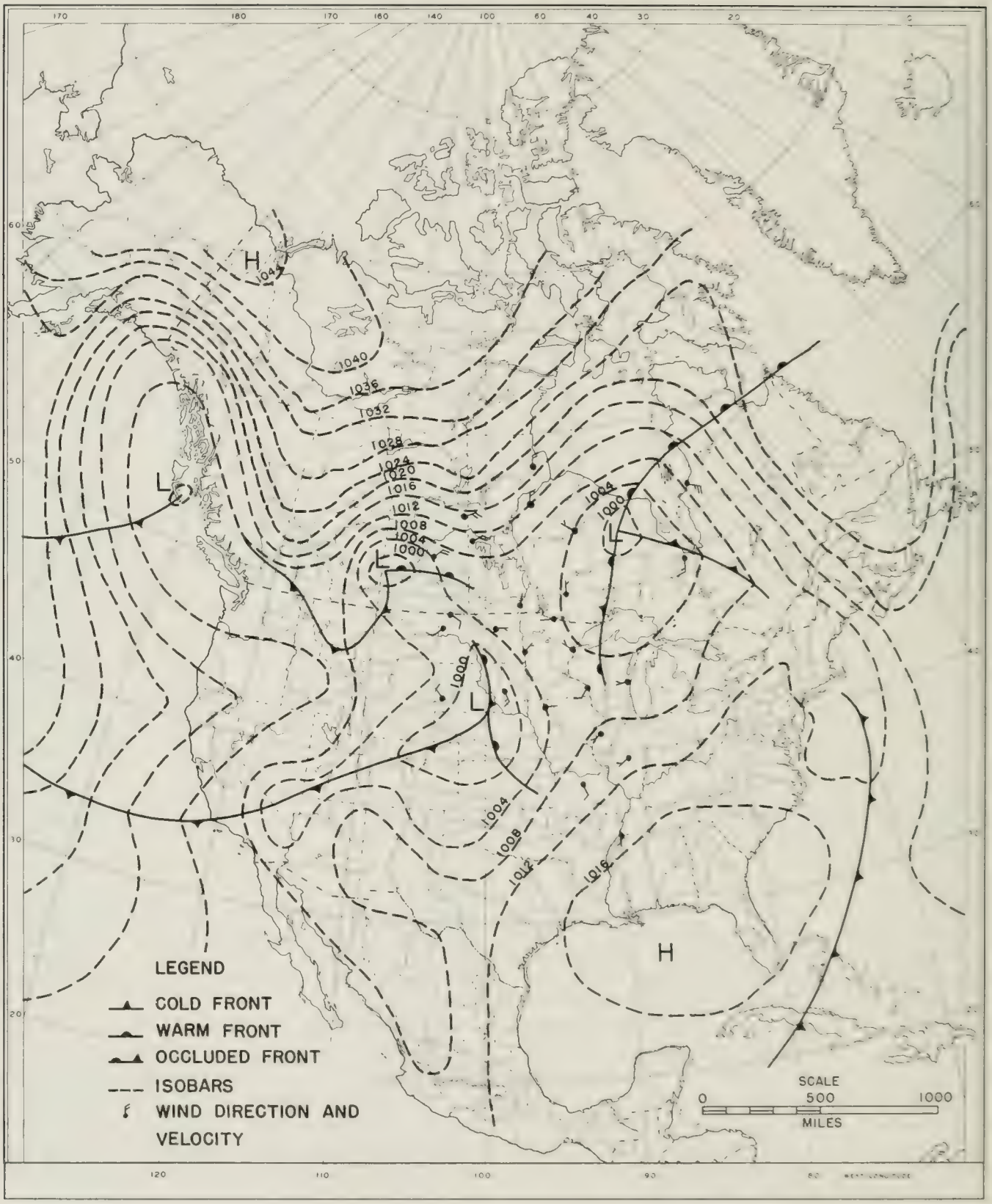


Fig. 3.--Weather conditions prevailing at 6:30 A.M., C.S.T., October 31, 1955; shown are pressure areas, isobars, fronts, and wind directions and velocities as reported by the United States Weather Bureau.

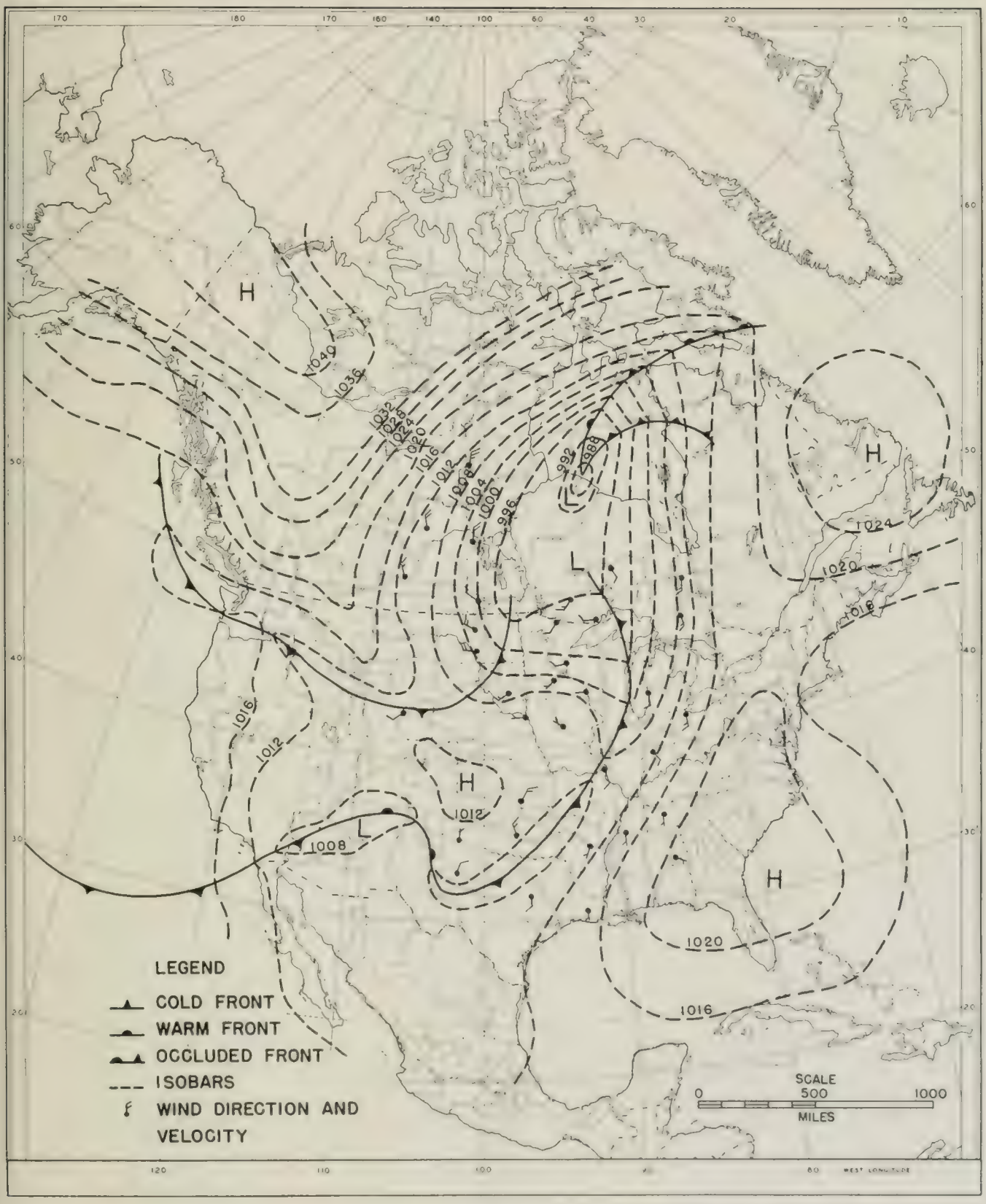


Fig. 4.—Weather conditions prevailing at 6:30 A.M., C.S.T., November 1, 1955; shown are pressure areas, isobars, fronts, and wind directions and velocities as reported by the United States Weather Bureau.

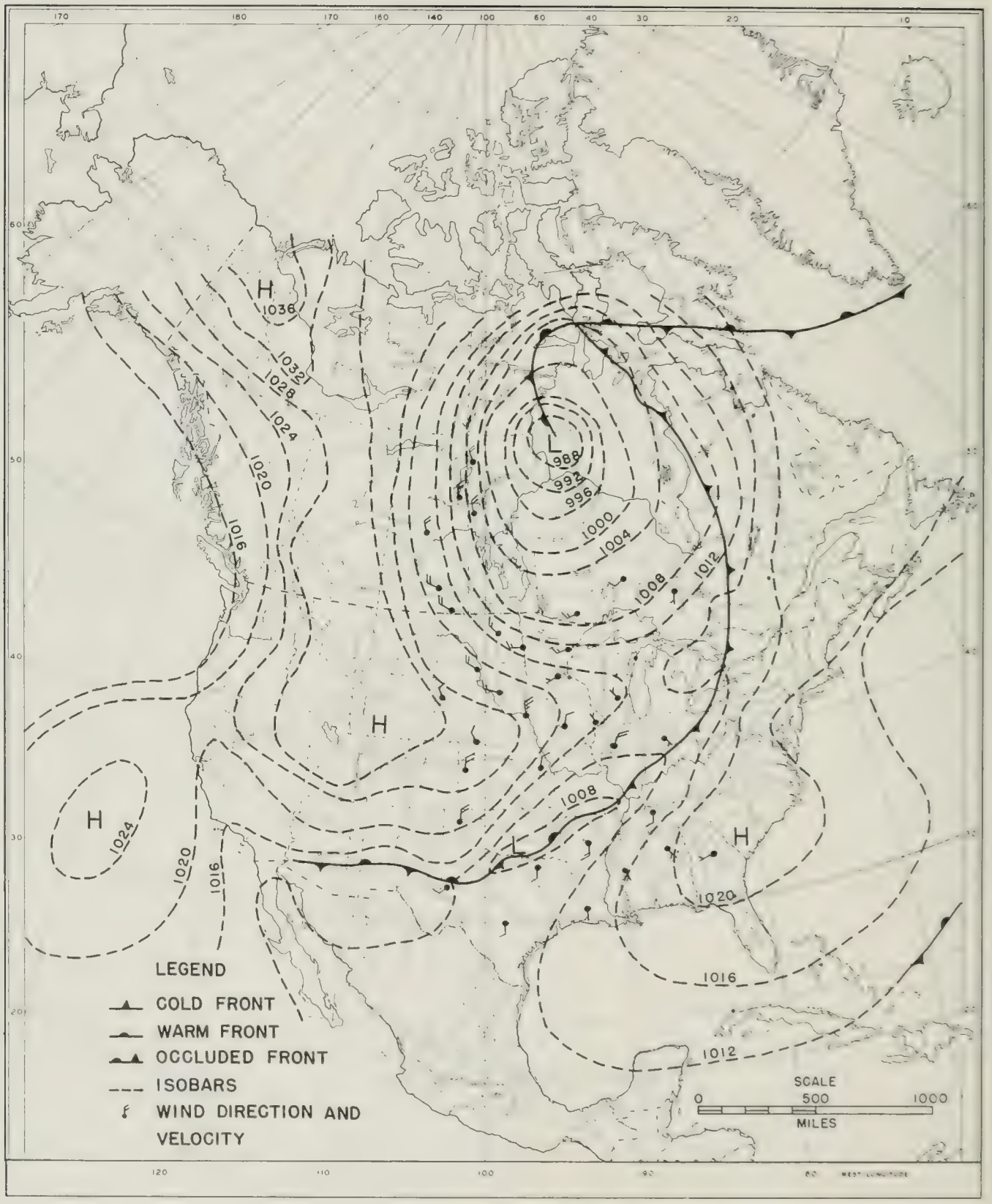


Fig. 5.--Weather conditions prevailing at 6:30 A.M., C.S.T., November 2, 1955; shown are pressure areas, isobars, fronts, and wind directions and velocities as reported by the United States Weather Bureau.

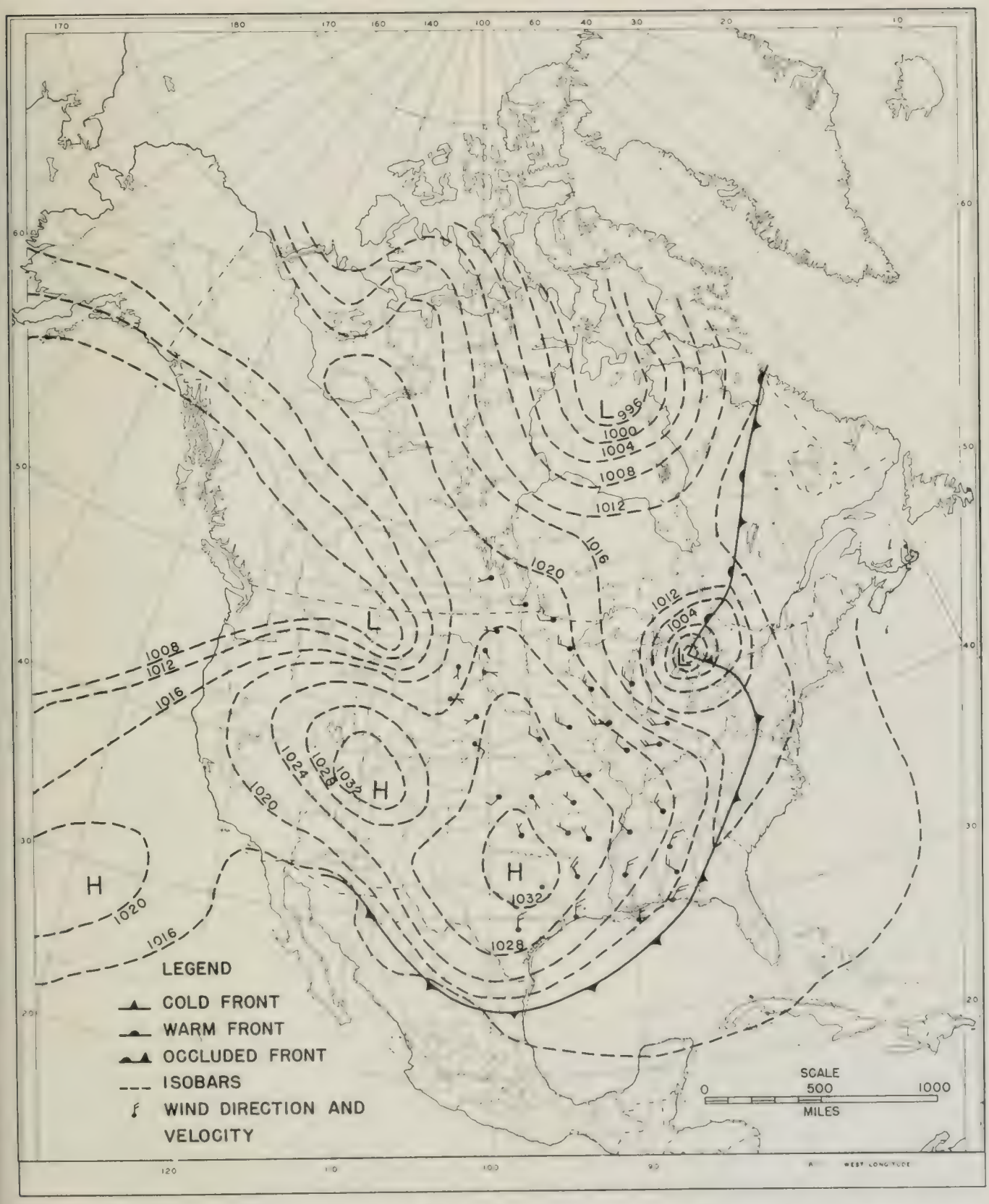


Fig. 6.--Weather conditions prevailing at 6:30 A.M., C.S.T., November 3, 1955; shown are pressure areas, isobars, fronts, and wind directions and velocities as reported by the United States Weather Bureau.

However, the heaviest snow fall appears over. The snow is expected to end over Alberta on Wednesday [November 2], but continue over the remaining regions." Snow was falling over North Dakota and northern Minnesota, also. Winds were under the influence of the deep low centered near Churchill, Manitoba.

November 2.--While the high pressure area remained centered over northern Yukon, an extension of this area moved south along the Continental Divide and, within this extension, a separate center was beginning to form over western Wyoming, fig. 5. The low pressure area in the vicinity of Churchill remained virtually stationary but deepened further. The weather in the north continued to be under the influence of this deep low. Snow continued to fall over most of Saskatchewan, Manitoba, and Ontario.

A secondary low pressure area, which had been developing over Arizona, New Mexico, and neighboring states on November 1, began to deepen on November 2 and move rapidly northeastward along the cold front; it reached southern Illinois by 12:30 P.M. and central Illinois by 6:30 P.M. This low brought overcast conditions, scattered snow showers, and strong winds to the Middle West. In the Mississippi Flyway, the cold front extended in a southwest-northeast direction from southern Missouri to north-central Ohio.

November 3.--By November 3, the weather in the southern part of the Mississippi Flyway was under the influence of a strong high pressure area centered over northeast Texas, fig. 6. With the clockwise flow of air around the high, winds from the northwest occurred in Iowa, Illinois, Missouri, Arkansas, and Mississippi. Wind velocities in these states generally ranged from 15 to 20 miles per hour.

The weather in the northern part of the flyway was under the combined influence of the low that had been over central Illinois on November 2, and that had moved to the vicinity of Georgian Bay, Ontario, by 6:30 A.M. on November 3, and of the high over northeast Texas. This combination produced strong northwest winds through Minnesota and Wisconsin.

TEMPERATURE RANGE

The average and minimum daily temperatures at Winnipeg, Manitoba, from mid-October through November 10, 1955, are shown in fig. 7. There was a sharp decline in temperature at Winnipeg on October 23 and 24, followed by a pronounced warm wave on October 25 and 26. Temperatures started dropping on October 27. The average temperature declined steadily from then until November 3. The minimum temperature declined for 3 days, rose on October 30 and 31, and declined again on November 1, 2, and 3.

DIRECTION, SPEED, AND ALTITUDE OF FLIGHT

Observations on the 1955 mass migration of waterfowl from the Great Plains of Canada into the Mississippi Flyway of the United States yielded information on direction or lines of flight, fig. 8, as well as on speed and altitude of flight. Accounts of flights of waterfowl over the Great Plains of Canada, the eastern regions of North Dakota and South Dakota, western and southern Minnesota, and parts of Wisconsin and Missouri made it evident that long flights were made without the benefit of landmarks provided by river systems. Nevertheless, concentrations of waterfowl observed following river valleys made it clear that at times the birds used river valleys as guide lines.

Lines of Flight.--Especially large numbers of waterfowl were observed following the Missouri River valley from central North Dakota to northern Missouri. One flight line apparently broke away from the Missouri River above Pierre, South Dakota, where the river bends sharply to the southeast, and crossed Nebraska to reservoirs near North Platte. This assumption is based upon a hiatus in the migration noticed to the west and another to the east of the North Platte region in Nebraska and upon the lack of migration immediately to the west of the easternmost counties of Kansas.

The flight of waterfowl following the Mississippi River valley increased steadily in numbers as the birds moved southward toward St. Louis, Missouri. Feeder flight lines crossing Iowa and northern Missouri from the northwest to the southeast added their ducks to the main stem flight line. In migrating southeastward across Iowa, waterfowl were observed following the valleys of the Wapsipinicon and Des Moines rivers.

Some flight lines moving southeast crossed the Mississippi River and placed approximately 750,000 ducks in the Illinois River valley and western Indiana. Small numbers of ducks moved into eastern Illinois and western Indiana from due north.

From St. Louis southward, the direction of movement of the main flight line was due south. This flight line did not at all times closely follow the channel of the Mississippi River but spread out as much as 40 or 50 miles to the east or west of it.

Small flight lines cut straight south over the Ozark Mountains of southern Missouri. Some waterfowl utilizing these lines of flight probably stopped in the Stuttgart, Arkansas, area, while others probably continued straight south into Louisiana. In central and western Louisiana, flocks of waterfowl were observed arriving from due north, indicating they had not followed the Mississippi River flight line.

Although waterfowl populations increased in Michigan and Ohio as a result of this early November

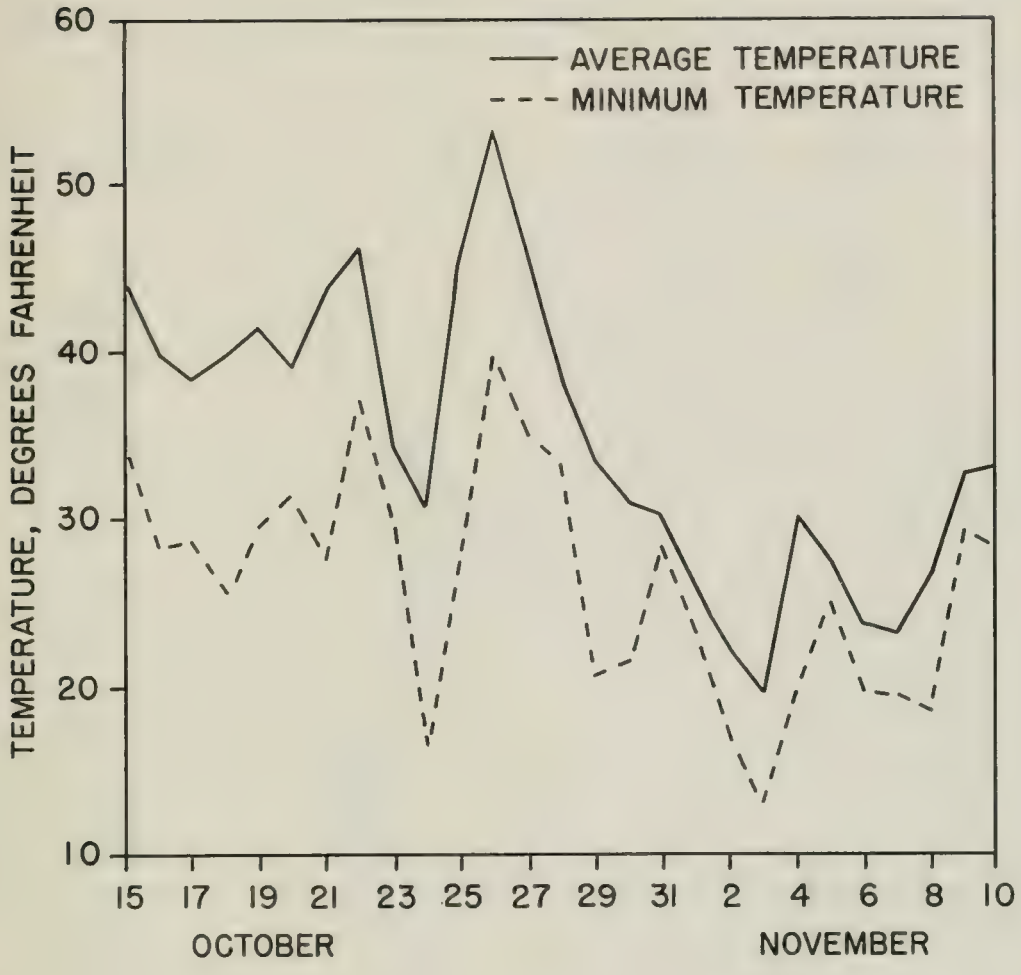


Fig. 7.--The minimum and average daily temperatures from October 15 through November 10, 1955, at Winnipeg, Manitoba, Canada.

flight, observations indicated that the increase was small compared with that in the western and central regions of the flyway.

Speed of Flight.--The mass waterfowl migration of 1955 moved with unusual rapidity from the Great Plains of Canada to the marshes of Louisiana. The exodus started from southern Alberta and Saskatchewan on October 31 and from Manitoba on November 1. The flight in the western sector of the Great Plains moved ahead of the flight in the eastern sector.

By early morning of November 1, the flight was in full force through North Dakota and along the northern part of the Missouri River in South Dakota. As interpolated from field reports, part of the flight was moving in front of and part was moving behind the cold front progressing southeastward through South Dakota and North Dakota, fig. 4. Farther east, in west-central Minnesota, the flight appeared near Detroit Lakes at 11:00 A.M. and, at other points, from 1:00 P.M. through the afternoon. In east-central South Dakota it was first

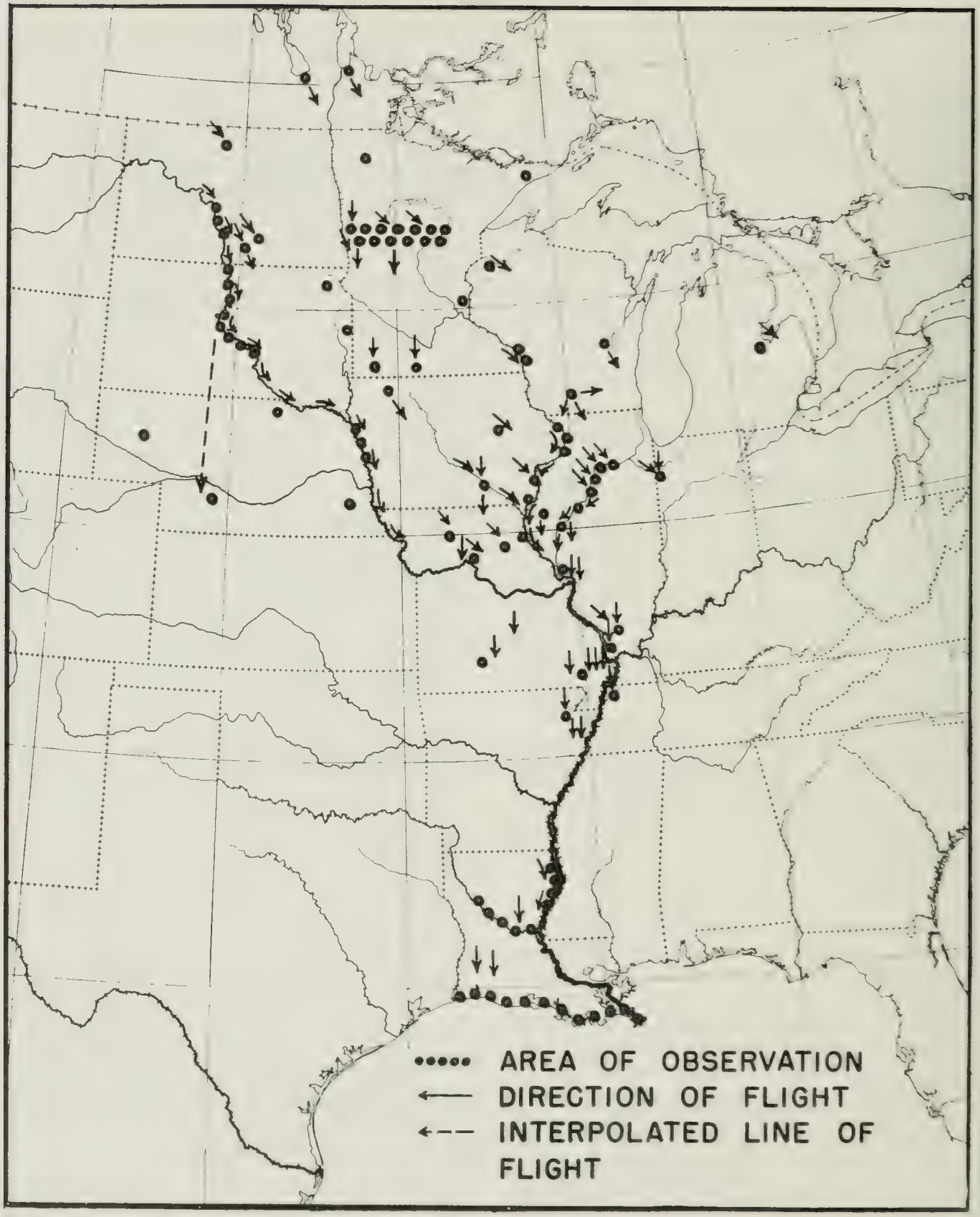


Fig. 8.—Areas of observation and directions of observed lines of waterfowl migration, November 1-3, 1955.

noticed at 2:00 P.M. By late afternoon the vanguards had reached southern Minnesota and northwestern Iowa.

Shortly after sunrise on November 2, the vanguards of migrating waterfowl reached Reelfoot Lake, Tennessee, and northern Arkansas. Later in the day, they showed up in northern Louisiana. The rear echelon of migrating waterfowl, which left southern Canada on November 1, reached Louisiana on November 3.

It is between 1,400 and 2,000 miles from various waterfowl marshes in southern Saskatchewan and Manitoba to southern Louisiana. Many thousands of ducks made this flight in 2 days. At an average speed of 40 miles per hour, these waterfowl would have flown this distance in 35 to 50 hours. It appears likely that some waterfowl made this flight without stopping.

While large numbers flew during the night, other waterfowl alighted on lakes and marshes to spend the night and resume migration the following day. The flight schedule is illustrated by population changes at Crane Lake, Bath, Illinois, where numbers rose from 65,000 in the morning to 120,000 by evening of November 2 and declined to 85,000 by the morning of November 3, and by Sieh's observations of mallards which alighted on Big Spirit Lake, Iowa, the afternoon and night of November 1 and took flight periodically throughout the morning of November 2.

Altitude of Flight.--Under fair weather conditions, waterfowl may fly so high as to be invisible, or almost so, to the naked eye. In aviating over Illinois, we have found ducks at maximum altitudes of 3,000 to 4,000 feet. Under storm conditions, or over large rivers, waterfowl commonly fly at much lower altitudes.

The storm conditions which prevailed at the time of the November 1 and 2 waterfowl migration resulted in the birds flying so low as to be readily visible from the ground. In North Dakota they were observed flying at 200 to 300 feet, so low that many of them were shot. In Minnesota, the highest ducks observed from a plane were at 800 feet, the lowest at 100-150 feet. Observers near several Iowa rivers estimated that flocks of ducks were flying at 100 to 800 feet. Over the state of Missouri, large numbers of migrating waterfowl were only 100 feet above the ground. Over the Mississippi River valley in Illinois, flocks of ducks were stacked at elevations of 200 to 2,000 feet. For a distance up to 40 miles west of the Mississippi River in southern Missouri, mallard flocks were at altitudes that ranged between 400 and 1,000 feet. Observers in a plane over northern Arkansas saw mallards flying at 1,500 feet.

SPECIES IN FLIGHT

Probably all species of ducks common in the Mississippi Flyway, with the exception of the blue-winged teal, were involved in the mass migration of October 31 and November 1 and 2, 1955. However, all observers concurred that the flight was predominated by the mallard, followed in numbers by the lesser scaup. Other species which appeared to be important components of the flight were the gadwall, pintail, green-winged teal, widgeon, and canvasback.

EFFECT OF WEATHER ON FLIGHT

The mass waterfowl migration emanating from southern Alberta and Saskatchewan on October 31 and southern Manitoba on November 1, 1955, was undoubtedly influenced by several components of weather. Which was the most important in triggering the migration is difficult to determine.

Barometric Pressure.--Weather conditions in Alberta, Saskatchewan, and Manitoba on October 31 and November 1, 1955, were associated with two low pressure areas. One low pressure area moved across the Great Plains from Alberta to Manitoba. The other low pressure area moved from Wisconsin to Churchill, Manitoba, where it deepened to influence weather conditions over much of the continent.

In a recent book on waterfowl, Hochbaum (1955:106-7, 137) stated that ducks select anticyclonic (high pressure) weather for the start of their mass migrations. He cited a specific observation on October 30, 1954, and "many similar observations" as evidence that high pressure, with its attendant clear sky and favorable wind, is a prerequisite for the beginning of mass migration. Certainly the migration which took place during the period October 31-November 3, 1955, the largest waterfowl movement in the Mississippi Flyway since November 11, 1940, was not begun under these conditions. Neither was the famous waterfowl migration on November 11, 1940, which was initiated by weather conditions associated with a deep low; the low moved rapidly into the Mississippi River valley from the southwest, creating the "Armistice Day storm" which made history.

Wind.--Recent studies of small birds strongly suggest that wind direction is an important factor in the initiation of their migration.

Devlin (1954:93) correlated wind direction with autumnal, nocturnal migration and concluded that birds were in flight on nights with light to moderate north or northwest winds. After studying bird migration in Lincoln Park, Chicago, Bennett (1952:219) concluded that "The autumn migration waves are associated with cold fronts followed by strong NW to N winds."

Dennis (1954:111) concluded after observing the spring migration of birds in Texas that "Southerly winds, rising temperature, and falling barometric pres-

Table 5.--The wind direction and the wind velocity in miles per hour for certain hours of the day, November 1 or 2, 1955, at several weather stations from southern Manitoba to southern Louisiana.

Hour of Day	Winnipeg, November 1	Minneapolis, November 1	Peoria, November 2	Memphis, November 2	Baton Rouge, November 2
0		W 8	NE 9	S 20	ESE 8
1	W 13	WNW 13			
3	W 14	NW 12	*N 9		
6	W 15	SW 11	*N 12	*S 17	ESE 8
9	W 16	SSW 13	*N 17		
12	*W 20	WSW 23	*N 19	*S 23	SSW 14
15	*W 16	WSW 23	NW 23		
18	*W 13	*WSW 11	NW 23	*NW 25	*SSW 17
21	*W 19	*SW 13	NW 17		
24	*W 24	*W 13	W 13	NNW 18	*N 15

*Hour of passage of spectacular waterfowl migration of late October and early November, 1955.

sure generally attend the departure of migrants." Raynor (1956:171) tentatively concluded that stable air and favorable winds aloft were of great importance for nocturnal bird migration during the spring.

Hochbaum (1955:104) stated that every major flight of blue-winged teals in September, canvasbacks and redheads in October, and lesser scaups and mallards in November occurred with a west-east opposition of high and low pressure areas, with a trough of wind flowing down the middle between the two air masses. He used the weather map of November 7, 1947, to illustrate the favorable flow of air for the waterfowl migration which occurred at that time.

Weather maps for October 31 and November 1, 2, and 3, 1955, figs. 3-6, show wind directions and velocities near ground level by means of arrows, and above ground level up to about 2,000 feet above ground level by means of isobars. The wind flows along the isobars; the closer the isobars, the higher the wind speed. The wind circulates counter-clockwise around a low pressure area, the reverse around a high pressure area.

Because, during the mass migration of 1955, waterfowl were migrating between a few hundred and 2,000 feet above the earth, they were under the influence of winds shown by both arrows and isobars. The winds were only partially favorable for southward migration. They were not beneficial on October 31 and November 1 in Manitoba, the Dakotas, Minnesota, and Wisconsin, when they were largely from the west at almost right angles to the line of flight. Table 5 shows the wind directions and velocities on certain hours during the period the mass migration passed several weather stations in the Mississippi Flyway. Seldom did the migrating waterfowl have a tail wind.

Wind directions were at least as favorable on October 29 as during the period October 31-November 2; yet comparatively little migration occurred on October 29.

Over a large area of flight on November 1-3, 1955, waterfowl were migrating through turbulent air, through snow showers in the northern sector, and under a layer of low, dense, and extensive clouds. Such conditions certainly made for hazardous flight and difficult navigation.

Temperature.--An interpretation of the effect of cold fronts on the mass waterfowl migration of 1955 is difficult because of the complicated frontal structure over the period of the migration. A cold front of Maritime and Continental Polar air, shown over the northwestern United States on the weather map for October 31, fig. 3, passed down the flyway to the Midwest as a secondary cold front of Continental Arctic air was moving behind it in southwestern Canada and northwestern United States, fig. 4. The leading edge of the secondary front was so diffuse as to make its position quite uncertain. In fact, the secondary front did not appear on the weather map for November 2, fig. 5. Eventually it combined with the Polar cold front on November 2 north of Memphis, fig. 5. The passage of a secondary cold front at a given point can best be ascertained by temperature decline. Usually winds shift with the passage of a front, but such was not the case with the secondary cold front shown on the weather map for November 1, fig. 4.

The average daily temperatures at Winnipeg, Manitoba, fell for 4 successive days before the mass migration started from Alberta and Saskatchewan on October 31 and 5 successive days before the migration started from Manitoba on November 1. Temperatures for this period are shown in fig. 7.

On November 1, the average temperature was 26.0 degrees and the minimum temperature 23.2 degrees,

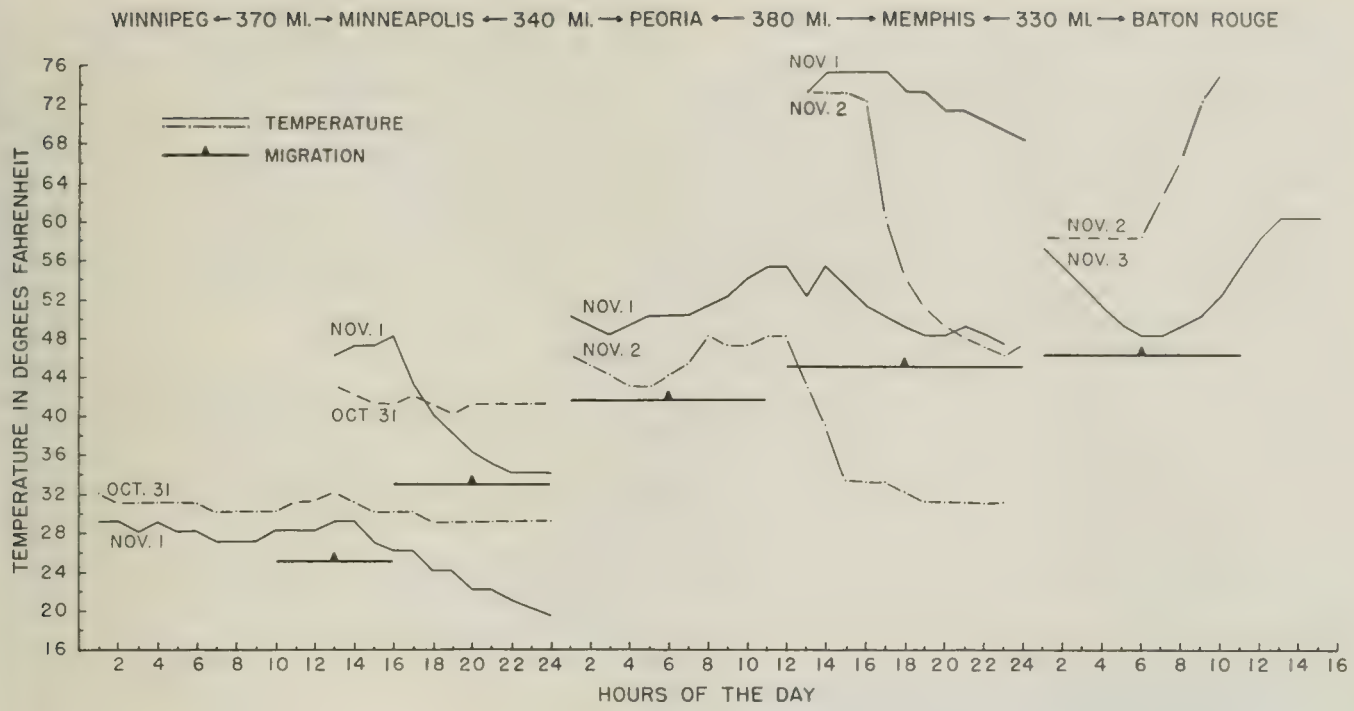


Fig. 9.--Hourly temperatures reported by weather stations at Winnipeg, Minneapolis, Peoria, Memphis, and Baton Rouge on the day before and the day on which the mass waterfowl migration of 1955 passed through the region of each of these cities; also the hours of greatest migration (indicated by heavy horizontal line) in each area, as interpolated from field reports.

while, on October 24, the average temperature was 30.8 degrees and the minimum was 16.6 degrees.

It is apparent that the minimum temperature on October 24 did not affect waterfowl migration to the extent a higher minimum did on November 1. It appears that the cumulative effect of the cold was more important in initiating migration than a single sharp drop in temperature.

Fig. 9 shows the hourly temperatures reported by five weather stations on the day before and the day on which the mass waterfowl migration of 1955 passed through the region of each of these stations. The stations were spaced almost equidistantly along the line of migration.

It is apparent that the mass waterfowl migration was well underway at Winnipeg, Manitoba, before the Continental Arctic air mass began to depress the local temperature at hour 15 on October 31. By hour 24, the temperature had dropped 10 degrees below the minimum of the previous day.

The front of Continental Arctic air pivoted around the low pressure area centered in southwestern Manitoba to swing eastward, thereby dropping the temperature at Minneapolis, Minnesota, at almost the same time as at Winnipeg. At Minneapolis the waterfowl flight arrived with the mass of Continental Arctic air, which dropped the temperature 7 degrees below the minimum of the previous day.

The main body of the waterfowl flight arrived at Peoria, Illinois, in advance of the mass of Continental Arctic air, which commenced to drop temperatures there at 1 P.M., November 2. Temperatures fell 17-20 degrees below minimum temperatures of the previous afternoon and night.

At Memphis, Tennessee, part of the main body of the waterfowl flight arrived before and part with the mass of Continental Arctic and Polar air, which dropped temperatures 22-24 degrees below minimum temperatures of the previous evening and night.

The Arctic and Polar air mass arrived at Baton Rouge, Louisiana, during the early morning of November 3, dropping the minimum temperature 10 degrees. Arrival of the waterfowl flight was concomitant with arrival of the cold air.

Precipitation.--When snow covers waste grain in harvested fields to the extent that it makes for difficulty in the feeding activities of mallards and pintails, an exodus of these species may occur. The extent of the exodus depends usually upon the depth of the snow. The small amount of snow that had fallen on the Great Plains of Canada by November 1 was not sufficient in itself to account for the mass departure of mallards and

pintails, nor to account for the complete departure of teals, widgeons, gadwalls, and diving ducks.

Analysis of Effect of Weather on Migration.--The effect of weather in initiating the mass waterfowl migration of October 31-November 1, 1955, is evaluated as follows: Low pressure areas in Canada resulted in a southward flow of a mass of Continental Arctic air. The low temperatures resulting from Continental Arctic air triggered the flight from the Great Plains of Canada and the United States. The flight moved faster than the cold air mass, so that at Winnipeg, Manitoba (where a stationary front slowed the southward flow of cold air), the migration of waterfowl was in advance of the Arctic air.

Because of a swinging gate action of the Arctic air, which pivoted around a low pressure area in southwestern Manitoba, the waterfowl flight arrived at Minneapolis with the cold front. By the time the flight reached Peoria, Illinois, it was again in advance of the Arctic air. The southward movement of cold air accelerated between Peoria and Memphis, Tennessee, so that part of the waterfowl flight arrived at Memphis before and part of it with the cold air.

LITERATURE CITED

Bennett, Holly Reed
1952. Fall migration of birds at Chicago. Wilson Bul. 64(4):197-220.

Devlin, Joseph M.
1954. Effects of weather on nocturnal migration as seen from one observation point at Philadelphia. Wilson Bul. 66(2):93-101.

Dennis, John V.
1954. Meteorological analysis of occurrence of grounded migrants at Smith Point, Texas, April 17-May 17, 1951. Wilson Bul. 66(2):102-11.

Hochbaum, H. Albert
1955. Travels and traditions of waterfowl. University of Minnesota Press, Minneapolis. 301 pp.

Raynor, Gilbert S.
1956. Meteorological variables and the northward movement of nocturnal land bird migrants. Auk 73(2):153-75.

Smith, Harry R., and Paul W. Parmalee
1955. A distributional check list of the birds of Illinois. Ill. State Mus. Pop. Sci. Ser. 4. 62 pp.